FARO ABANDONMENT PLAN

INFORMATION PACKAGE

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List of Contents:

TERMS OF REFERENCE FOR DEVELOPMENT

OF FARO MINE ABANDONMENT PLAN

1. Components of mine facilities to be considered in abandonment plan:

   (a) Water supply reservoir
   (b) Tailings pond surface physical and chemical stability
   (c) Rose Creek diversion canal
   (d) North Valley wall diversion ditches
   (e) Faro Creek diversion
   (f) Pit
   (g) Waster dumps
   (h) Pumphouse pond and associated facilities

2. The abandonment plan must evaluate all possible alternatives for permanently reclaiming the above structures, identifying the best option from environmental and economic points of view.

3. The investigation must be balanced such that components of little significance or concern are covered relatively superficially, allowing maximum focus of effort on the obvious problem areas.

4. The emphasis throughout will be on arriving at an abandonment plan which protects water quality as a first priority, with aesthetics and possible alternative land uses as secondary objectives.

5. The development of the abandonment plan should proceed in stages, with formal CAMC/consultant/government review at each stage.

   Stage I: Selection of consultant and development of terms of reference and schedule.
   - complete by December 31 -

   Stage II: Site visit and review of all CAMC/government information. Overview of all project components to determine areas needing detailed study and intensive effort. Outline of proposed "plan of attack" on problem areas. Identify those components of the mine facilities which can be reclaimed easily with existing technology and which will not present long term maintenance problems - eliminate these from further consideration with superficial treatment.
   - complete by January 31 -

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Stage III: Carry out whatever detailed investigations are needed to get acceptable solutions to the problems identified in stage II. These detailed investigations will include development of ways to guarantee the stability of the Rose Creek diversion in the long term and will include a detailed evaluation of present "state-of-the-art" options for physically and chemically stabilizing the tailings surface, but will not necessarily be limited to these. In most cases more than one method of reclamation may be possible at different levels of environmental risk and economic cost.
- complete by May 31 -

Stage IV: Compilation of final report and presentation to the Water Board.
- complete by June 31 -

YUKON TERRITORY WATER BOARD

200 RANGE ROAD
WHITEHORSE, YUKON
Y1A 3V1

31 October 1980

Cyprus Anvil Mining Corp. Ltd.
Box 1000
Faro, Y.T.

Attention: John Carrington

Dear Sirs:

Re: Abandonment Plan for Proposed Tailings Disposal System

The Yukon Territory Water Board met with Messrs. N. G. Cornish and P. Dean on October 27, 1980 to discuss the objectives of Cyprus Anvil's abandonment plan for the proposed expansion of the Tailing Disposal System. The Board, at that meeting, stressed the need for the plan to meet the following objectives:

1. The abandonment plan must ensure the long term, safe and competent physical containment of the tailing;

2. The abandonment plan must ensure that the long term water quality of Rose Creek be equal to or better than that during operation.

In consideration of those objectives the Board stated that all associated aspects of the mine site which could possibly compromise a proposed plans' ability to achieve the above objectives should be considered in the plan. Some aspects raised were:

a) The proposed Rose Creek diversion channel.

b) The water supply reservoir.

c) The pumphouse works.

d) The stabilization of the north fork of Rose Creek, including diversions.

e) The stabilization of Faro Creek.

f) The north slope drainage system.

g) The stabilization of the tailing surface.

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h) The long term water quality of seepages and groundwater discharge from the tailings s¯stem, including the consideration of any treatment facilities.

The Board requested that the abandonment plan be developed timely and that the level of detail in the plan be adequate to enable it to determine the engineering, economic and environmental viability of the abandoned facility. As stated to the Company at the meeting, any abandonment plan must be accompanied by a commitment and a means by which Cyprus Anvil Mining Corporation will undertake the plan if approved.

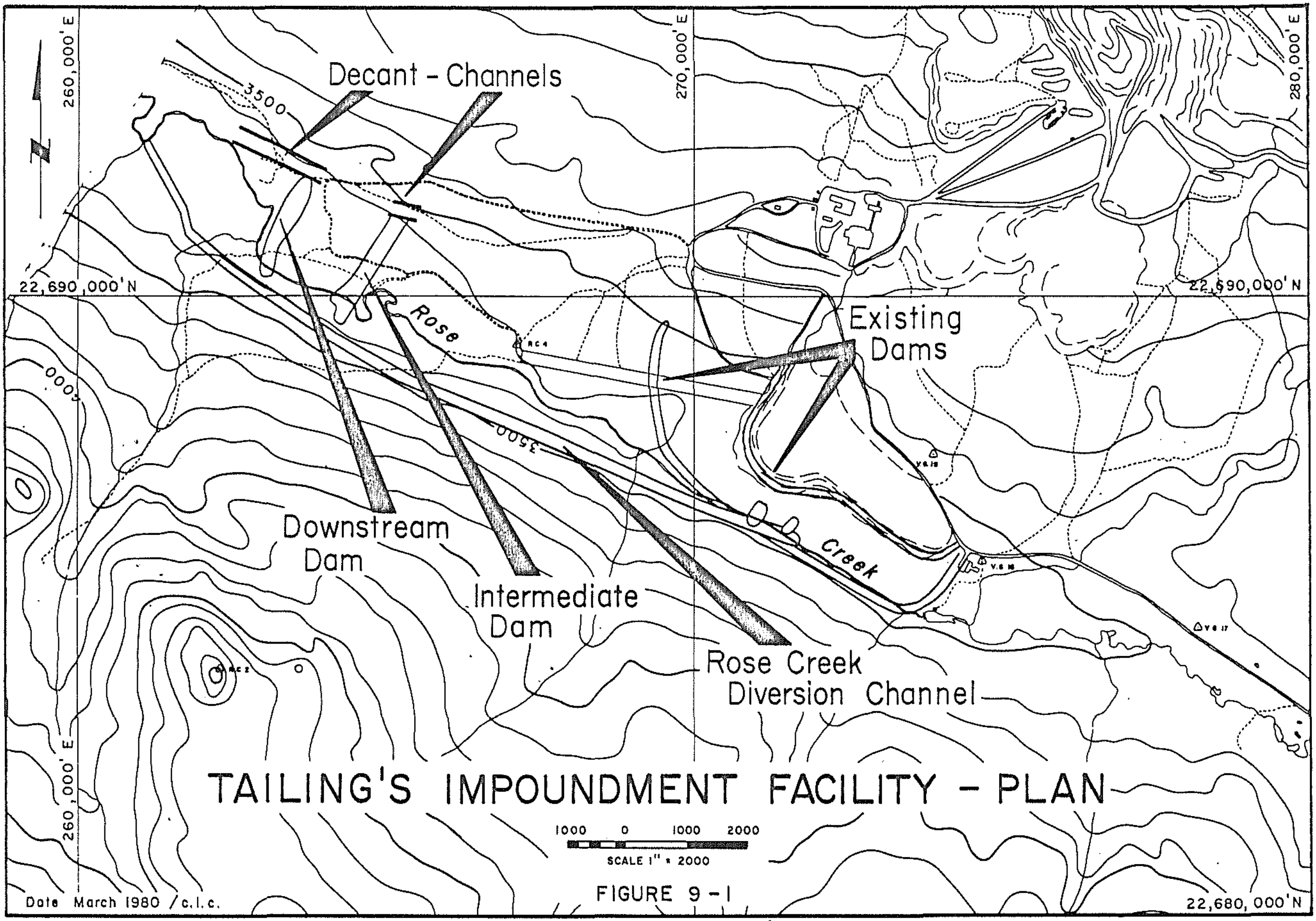
The Board suggests that an early meeting with Departmental staff be held to initiate discussions regarding any questions you may have on the subject of abandonment.

Yours truly,

P. D. Beaubien

for John Scott, P. Eng.,
Chairman,
Yukon Territory Water Board

cc: Mr. N.G. Cornish
cc: Mr. P. Dean



TAILING'S IMPOUNDMENT FACILITY - PLAN

FIGURE 9-1

1.0 SUMMARY

The Down Valley Tailings Project was conceived in May, 1979 and during the past year detailed study has been undertaken in anticipation of construction beginning in October, 1980 and carrying through to the fall of 1981. Golder Associates has conducted a number of field investigations and office studies on behalf of Cyprus Anvil with the purpose of developing an appropriate design for the project. This report provides Golder Associates' final design recommendations.

The Down Valley Tailings Project consists of a Diversion Canal to bypass Rose Creek around the tailings deposits which will fill the bottom of the Rose Creek valley, a Cross Valley Dam to retain spent tailings water for a 60 day retention time, and a cross valley Intermediate Dam which will be constructed in stages to retain tailings in the valley bottom. Additional project elements of lesser importance include a North Valley Wall Interceptor to prevent uncontaminated drainage runoff from entering the tailings system, a Diversion Dam which is necessary to achieve creek diversion from the existing canal to the new canal and the spillways and decants necessary to ensure the integrity of the cross valley dams.

The proposed Rose Creek Diversion Canal has a design hydraulic capacity equivalent to a 50 year return period flood and contingency capacity for the 500 year return period flood, the latter assuming no freeboard on the engineered section. In addition, a low flow pilot channel is provided to diminish the tendancy for winter glaciation and low flow meandering. The proposed 3.6 km alignment follows along the south valley wall of the Rose Creek valley. Because the canal channel grade of 0.19 percent is flatter than the natural valley bottom grade of 2 percent, tailings storage capacity is generated below the elevation of the diversion canal. At the location of the Cross Valley Dam the Diversion Canal invert is about 25 m above the valley bottom. At this point the return of the diverted creek to its natural channel is initiated using a

rock drop weir system similar in construction to that presently operating in the existing diversion works.

The canal excavation will traverse a variety of materials ranging from bedrock to glacial till and creek alluvium. Much of the route is through permafrost and, because construction will induce thawing of these sometimes ice rich materials, a filtering and insulating gravel layer will be required. It will be necessary to construct the canal during the winter months to avoid thaw degradation during construction. Total earthworks volume for the canal is estimated to be 950,000 m^3 plus some 84,000 m^3 of erosion protective rock work.

Cross Valley

Both the Cross Valley and the Intermediate Dams are to be of zoned earthfill and the former will have an upstream blanket attached to the glacial till core to reduce foundation seepage to an acceptable level. The alignment of the Cross Valley Dam has been chosen to minimize foundation interaction with a permafrost area but some excavation of unsuitable and frozen materilas will still be necessary. Seepage reduction at the Intermediate Dam will involve excavation through the terrace gravels to creek level and use of a sloping glacial till blanket on this borrow pit face. Combined Stage I earthworks for these dams is approximately 870,000 m^3.

Emergency spillways are provided for each dam as an insurance against overtopping of the dams in the event of failure of the diversion canal system or the occurrence of flows in excess of canal capacity. The design capacity of these spillways is for a 50 year return period Rose Creek flood flow and their intended function is to protect and maintain the crest of the dams. Decant channels are located adjacent to the spillways to pass on a routine basis the tailings spigot water flows.

The Diversion Dam is a relatively small structure required to divert the creek from its existing route into the new diversion canal. It is intended that this structure will be built in the wet using a rockfill starter dyke with progressively finer materials being dumped upstream of the rockfill.

The North Valley Wall interceptor consists of a simple unarmoured channel cut in the generally unfrozen till deposits of the North Valley wall. Hydraulically the required cross section is based on a 50 year design return period.

This report discusses the various stages and procedures of the investigation, the findings of the investigation and studies, and the recommended designs for construction. A summary of project construction quantities is provided in Chapter 8. A general project summary is presented below.

GENERAL PROJECT SUMMARY

Primary Construction Elements

Length of Diversion Canal:	3600 m
Length of Cross Valley Dam:	500 m
Height of Cross Valley Dam:	17 m (max)
Length of Intermediate Dam:	500 m
Height of Intermediate Dam:	17 m (max)
Ultimate Height of Intermediate Dam:	31 m (max)

Retention Pond

Area of Retention Pond:	32×10^4 m^2
Volume of Retention Pond:	1.4×10^6 m^3

Tailings Storage

Approximate Stage I Volume:	11×10^6 m^3
Ultimate Volume:	20×10^6 m^3

(based on 2 percent tailings slope)

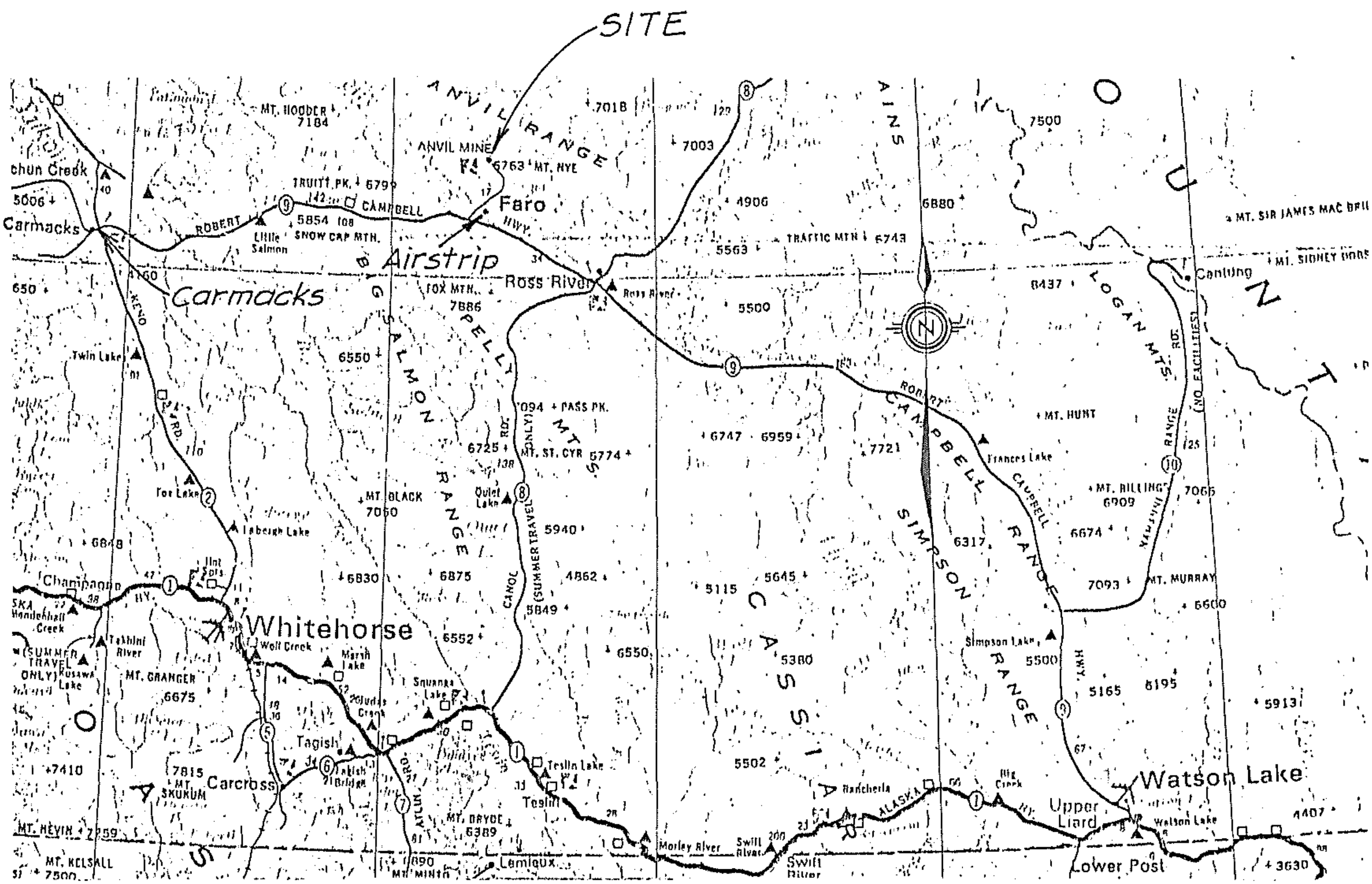
2.0 INTRODUCTION

Cyprus Anvil Mining Corporation plans to expand the tailings facility at their Faro, Yukon lead-zinc mine (for location see Figure 2-1) to provide storage capacity related to milling of recently acquired reserves. The proposed tailings storage expansion is referred to as the "Down Valley Project".

The Down Valley Project utilizes the Rose Creek Valley downstream of the existing tailings facility and as such is an extension to the existing facility which has been in use since plant operations began in 1969. The proposed expansion is expected to provide storage for about 20 million m^3 or about 40 million tonnes of tailings, depending on deposited tailings density in place which in turn depends on spigotting practice. This available volume does not include an additional 4 million m^3 which could be included if tailings were to be stored to the crest of the canal dyke; this will be possible if the seepage through and beneath the canal dyke is within acceptable limits. The actual tonnage which may be stored in the available volume depends on spigotting practice, mill grind, and ore source. Dry solids densities observed at the Lakefield Research test grind tailings pond ranged from 2.4 tonnes/m^3 for above water deposition down to 0.9 tonnes/m^3 (measured indirectly) for below water deposition. These observations suggest a need to understand and control the process of tailings deposition to optimize available storage.

As an outgrowth of its standing involvement in Cyprus Anvil's tailings disposal since 1973, Golder Associates' terms of reference for the Down Valley Project describe full involvement with respect to the design and construction supervision of the various project elements in accordance with the design objectives defined by Cyprus Anvil. Primary project elements consist of a 3.6 km long "diversion canal" along the south valley wall to isolate Rose Creek flow from the tailings deposits, an "intermediate" cross valley dam to retain spigotted tailings and a second "cross valley" dam to provide a 60 day retention time for spent tailings water. Secondary elements of the proposed scheme include a relatively small diversion dam, spillways and decants across the cross valley dams, and a north valley wall interceptor to collect uncontaminated surface flows which would otherwise flow down the north valley wall and enter the tailings disposal area. All project elements are illustrated on Figure 2-2.

Project No. 192-2025 Drawn KK Reviewed Date 18 Sep 79



SCALE: 1 in. to 40 mi.

LOCATION PLAN

Figure 2-1

Golder Associates

3.0 PROJECT SETTING

The project is located in the Rose Creek Valley near Faro, Yukon Territory. Rose Creek is an underfit stream which meanders its way along the valley bottom eventually entering Anvil Creek which in turn flows into the Pelly River. The bottom of the valley is about 400 m wide and it has been infilled by gravel deposits up to 40 m thick. Rose Creek winter flows are about 0.3 m^3/sec. whereas summer flows are typically 3 m^3/sec. Variable peak spring flows of up to 33 m^3/sec. occur during the late May, June, or early July periods. Detailed flow data may be found in Appendix I.

Climate in the area of interest is somewhat influenced by the mountain coastal factors. Temperatures at Anvil minesite on the mountain are often warmer than at Faro or in the valley bottoms during winter as a result of inversion phenomena. In December, 1979, temperatures in the Rose Creek valley bottom were often observed to be about 5°C lower than mine temperatures. The mean annual air temperature at the minesite is about -3.7°C. The coldest month is January with a mean daily temperature of about -20.8°C. The warmest month is July with a mean daily temperature of 11.1°C. Mean annual precipitation is 410 mm of which 211 mm is snowfall. Average daily temperatures are estimated to be below 0°C between September 5 and May 2. Supplementary climatic data is included in the Appendix II.

Discontinuous permafrost is present in the valley bottom and on the valley walls. Most of the south valley wall (see Figure 2-2 for orientation) consists of frozen coarse glacial till whereas much of the north valley wall is unfrozen similar material. Isolated pockets of occasionally ice rich frozen sands and silts may be found on the valley floor. The permafrost is characteristically "warm" with temperatures in the 0° to -1°C range.

The valley walls, particularly the south valley wall, are mantled with a moss cover about 0.3 m thick. Spruce trees range in diameter up to a maximum of about 0.4 m with typical sizes being about 0.2 m or less.

Tree heights are typically less than 10 m. Tree densities on the valley walls range up to 220 trees per hectare and are typically about 100 trees per hectare. On the valley floor barren areas occur where the gravel terrace deposits adjacent to Rose Creek are well drained.

4.0 DESIGN OBJECTIVES

In addition to the requirement for design of stable, economical and practical project elements, consultations with Cyprus Anvil have defined the following design objectives:

(i) that all Down Valley Project structures be designed to resist earthquake, it being assumed that all other structures not constructed as a part of the tailings project such as the fresh water impoundment dam will remain stable;

(ii) that the diversion canal water level be above that of the tailings storage pond;

(iii) that the drop weir energy dissipation system which has been operating successfully in the outfall of the existing diversion canal and has previously been approved by the Yukon Territorial Water Board and Department of Fisheries be adopted in principle for the new diversion canal outfall;

(iv) that the seepage losses from the canal into the new tailings pond should not exceed the lesser of 0.15 m^3/sec. (2000 i.g.p.m.) or 10 percent of the Rose Creek flow at the inlet to the facility (flows greater than the 50 year return period flood being excluded);

(v) that the alignment of the canal be chosen such that a 50 year return period flood of Rose Creek would be contained within the cut banks of the canal, the existing ground surface being used as a reference;

(vi) that the design capacity of the canal would be for a 50 year return period Rose Creek flood with contingency capacity for a 500 year return period flood;

(vii) that the outfall portion of the canal be designed for the same flows as the canal proper;

(viii) that the Cross Valley Dam be constructed to an ultimate elevation such that 60 days of retention time or approximately 1.4 million m^3 of storage would be available for chemical aging of tailings water;

(ix) that the seepage through the Intermediate Dam and its foundation should not exceed 0.22 m^3/sec. (3000 i.g.p.m.) to impound water behind this dam and therefore eliminate winter glaciation.

(x) that the seepage through the Cross Valley Dam and its foundation should not exceed 0.15 m^3/sec. (2000 i.g.p.m.) to ensure adequate retention time and permit some water reclaim for plant use.

7.0 PROPOSED DESIGN AND CONSTRUCTION

Each of the elements of the Down Valley Project is located on Figure 7-1. The investigation profile baselines are also located on this plan for reference.

The proposed designs of each one of the project elements are presented here. It is noted that the technical support data for these designs may be found appended to this report as follows:

Appendix VI - Cross Valley Dam Design
Appendix VIII - Diversion Canal Geothermal, Seepage and Stability Considerations
Appendix IX - Hydrologic and Hydraulic Design
Appendix X - Earthquake Data, Peter Byrne Review

Important discussions included in these appendices pertinent to construction of the various project elements, to post construction monitoring and instrumentation, and to maintenance are not reiterated here for brevity.

7.1 Diversion Canal

The alignment of the proposed canal was chosen, based on the design assumption that it is desirable to keep the canal in cut as much as possible because postulated winter construction would probably preclude the building of dependable dykes. Sidehill canals are generally most economical if balanced cut/fill is attempted but such a solution is anticipated to result in unacceptable seepage losses through poorly compacted dykes. Therefore a 50 year flood in cut criteria was adopted to locate the canal route meaning that the centreline of the canal was located such that the downhill channel cut was 2.4 m with respect to the natural ground surface. Use of this criteria has resulted in a ratio of excavation volume to fill volume of about 4 to 1 and, in spite of this, some significant fills are required locally to maintain an acceptably smooth alignment. Where these fills are required it is recommended that the dykes be constructed in thawing conditions to permit proper compaction. This constraint will mean that the diversion canal will not be functional before the spring flood. Alternatively it may be desirable to accept larger excavation volume or a more tortuous alignment and thus to avoid the potential seepage problems of locally shallow cuts and locally large fills.

The standing canal alignment is shown on Figure 7-1. It is expected that this alignment will require some modification when the final survey cross-sections have been obtained.

The proposed cross-sections for construction of the canal are presented on Figures 7-2, 7-3 and 7-4. The hydraulic cross-section of the canal is based on the recommendations provided by Hydrocon Engineering Ltd. and their report contained in Appendix IX for reference. With 1 m of freeboard the section is capable of carrying a 50 year design flood. With no freeboard the section is anticipated capable of passing a 500 year flood and this is referred to as the contingency design flood.

There are three possible basic cross-sections which are anticipated necessary to accommodate the expected range of soil and rock conditions along the route. These sections will reflect:

(i) full thermal protection only
(ii) seepage control and thermal protection
(iii) channel excavated in rock

The <u>full thermal protection</u> alternative shown on Figure 7-2 requires that a 1.7 m thick gravel blanket be placed against the 2 horizontal to 1 vertical design sideslopes. This gravel blanket is intended to insulate and thus reduce the rate of thaw of otherwise problematic permafrost. Reduced rate of thaw permits drainage to occur in which case the thawing soil retains strength. The gravel blanket also serves to filter locally ice rich pockets which would otherwise flow and possibly lead to retrogressive degradation of the slope. Lining the diversion canal with gravel will also improve the erosion stability of the canal at most locations because it is normally coarser than the tills in which the channel will be cut.

At some locations along the canal route the materials are not continuously frozen or frozen ice rich. This does not preclude the use of the gravel blanket because areas which overlie these thaw-stable or thawed zones are usually ice rich and therefore require thermal and seepage filtering protection. Furthermore, permafrost may underlie thaw-stable zones. The practical solution to these broadly variable soil conditions is to simply blanket the entire cut slope with gravel and accept that, where thermal insulation and filtering are not critically important, some additional erosion protection is provided against both stream flow and down slope surface drainage.

The base of the excavation is generally flat and therefore virtually no soil shear strength is required to maintain stability. It is also noted that ice rich soils appear to be uncommon at depth. For these reasons the canal bottom blanket thickness is reduced to 0.8 m, consisting of 0.5 m of Class A rock for erosion control and 0.3 m of gravel filter between the rock and the natural soils.

The dyke which forms the downslope bank of the canal and is common to all 3 cross-section alternatives should be compacted according to a procedural specification. Relatively dry selected canal waste excavation should be used in these dykes and compacted immediately after excavation to take advantage of the relatively warm permafrost when compared to ambient air temperature. As stated above, where relatively high dykes occur the construction should be undertaken under thawing conditions.

The seepage control and thermal protection alternative shown on Figure 7-3 utilizes a 1 m thickness of compacted till as a seepage reduction liner. The need for such seepage control should be assessed according to the seepage control criteria established in Appendix VIII, namely, that the canal should be lined in areas where the soil exhibits a permeability greater than 10^{-4} cm/sec. The lining till material should be selected from the waste excavation materials, should be unfrozen, should be placed in thawing conditions at about standard Proctor optimum moisture content (7.8 percent) and should be compacted to maximum standard Proctor dry density (2100 kg/m^3) in maximum lift thicknesses of 0.3 m. The till is considered suitable if it has a minimum of 20 percent by weight passing the No. 200 sieve.

Between Sta. 0+000 and 0+700 of the Diversion Canal occurrences of relatively coarse till or alluvial deposits have been noted. Although all laboratory gradations of these materials are such that a permeability lower than 10^{-4} cm/sec. is expected, it is possible that local occurrences of coarser materials will be exposed during excavation that will require lining. For this reason it is important to monitor the excavation materials. Of principal concern are the bedrock occurrences which may form the bottom of the canal channel. While the seismic refraction surveys have generally indicated the rock to be of good quality, some disturbed and jointed bedrock has been noted. The area in the vicinity of the prominent creek at Sta.0+600 is one area where lining may be required. Others include those areas where rock may be encountered within the depth of excavation, namely:

(i) in the vicinity of the canal inlet.
(ii) Sta. 0+050 to 0+230
(iii) Sta. 0+330 to 0+350
(iv) Sta. 0+500 to 0+820
(v) Sta. 1+490 to 1+600
(vi) Sta. 1+940 to 1+980
(vii) Sta. 2+200 to 2+980

As an alternative to till lining in the rock, it is also possible that grouting of the fractures would successfully control seepage. The success of this labour intensive technique will depend on the degree of rock disturbance. Grouting operations should be completed in nonfreezing conditions.

If the base of the canal excavation is ice rich or extensive ice lensing occurs within the 50 year design flood depth, seepage losses may become a concern upon thaw. In such cases it would be adviseable to construct the seepage control cross-section (as discussed previously and during thawing conditions). Over-ripping of the downslope cut bank of the canal is another undesirable situation which may require the placement of a till blanket on the downslope cut face.

Where intact bedrock is encountered the excavation sideslopes may be steepened to 0.5 horizontal to 1 vertical as shown on Figure 7-4. If the rock is disturbed and fractured either the seepage control cross-section described above will be required, necessitating flattening of the side-slopes to 2 horizontal to 1 vertical, or the rock may be grouted if a successful product results.

Where the depth to bedrock is uncertain the canal should be staked as though seepage control or thermal protection is required. When bedrock is encountered a bench may be exposed and the excavation completed with steeper sidelopes. If poor quality rock is revealed the possibility remains that the rock bench can be cut back and lined with till. The rock excavation will require blasting and it is important that the rock not be unduly disturbed outside the excavation for reasons of seepage loss control and possible deficient stability.

It is probable that the canal lowside cutslope will expose bedrock having some planes of weakness dipping into the excavation. The attitudes of these planes of weakness are not known but it is expected that the 0.5 horizontal to 1 vertical sideslopes can be used at the hazard of having only small block failures which would daylight on the exposed bench where rock pick up could be treated as a maintenance item if it occurs after construction is complete.

If there is no doubt that the upside cut of the canal can be made in intact rock below the 50 year flood level it may be possible to stake the upside cut according to rock cut only. Furthermore, cut slopes steeper than 0.5 horizontal to 1.0 vertical may be acceptable on the upslope side of the canal.

Along the route of the proposed canal there are 2 relatively major valley wall creeks which must be intercepted. These are at Sta. 0+600 and 3+100. The flow in these creeks varies substantially from more than 0.2 m^3/sec in the spring and summer down to virtually zero flow at certain times in the winter. The proper interception of these flows is important because sizeable glaciations across the diversion channel might eventually choke off the Diversion Canal. In general, the interception design approach should be to prevent heat loss from the flowing water and to keep velocities high and the flow concentrated. Possible designs for these interceptions are presented in Appendix IX where it is also recommended that the interceptions be field engineered.

Appendix IX also discusses the occurrence of relatively small and intermittent valley wall streams and possible designs for their interception. It is noted that one of these streams occurs in the vicinity of the test excavation and that, in the course of construction, a slope icing up to 0.4 m thick was encountered in the vicinity of Sta. 1+900. No special interception installations were made and the behaviour of the excavation in this area should better define the need for and requirements of small stream interceptions. Artificial stimulation of glaciation uphill of the proposed canal could serve as a short term solution if canal icing problems develop and this would permit evolution of optimal interceptions as necessary.

Erosion control in the canal along the 0.19 percent grade reaches should be provided by lining the channel bottom and wells to the 500 year flood elevation with Class A riprap as discussed in Appendix IX. Initially it was intended to windrow cobbles from the gravel fill lining and place these on the channel slopes but this operation was found to be somewhat unsuccessful when constructing the test excavation. The resulting riprap was not continuous and the gravel borrow pit was sufficiently variable to render impractical the generation of slope protection by this method. Furthermore, gravel segregation was not possible on the bottom of the canal.

Grade control buried weirs or sills are also discussed in Appendix IX. The necessity and frequency of these structures will be determined in the field; they are recommended where the distance between canal rock excavations exceeds 250 m.

The proposed drop weir and rock lining to be used in the canal outfall is illustrated on Figure 7-5. The design shown is considered to be a practical extension of the recommendations of Appendix IX and the weir section is considered to be more robust than that which is now employed for the smaller flood flows carried by the existing channel. Parts of the canal outfall will be excavated in permafrost and generally the rock fill generated will serve as an insulation substitute for gravel. Nevertheless, it is particularly important to place a gravel filter between fine grained ice rich soils exposed by the excavation and the rock filter lining to ensure that sinkholes do not develop through unwanted internal erosion of the channel walls.

7.2 Cross Valley Dam

Design considerations for the construction of the Cross Valley Dam are documented in Appendix VI. The proposed cross-section is shown on Figure 7-6.

The Cross Valley Dam will be constructed to its final design crest elevation of 1065 m during the summer 1981 Stage I construction. This will provide a water storage between the Cross Valley and Intermediate

Dams of about 1.4 million m^3, equivalent to about 60 days of inflow at 0.27 m^3/sec.

The alignment of the Cross Valley Dam has been shifted downstream in the south abutment area from that which was initially designed. This has become possible because the final crest elevation of the dam has been reduced and desirable because ice rich permafrost tends to feather out as one moves downstream of Borehole No. 79-18. The new alignment reduces significantly the amount of difficult frozen foundation subexcavation required. Extrapolation of the February, 1980 borehole information suggests a fine-grained permafrost limit as shown on Figure 7-1 and suggests that relatively minor amounts of permafrost removal will be required near the upstream toe of the dam.

The proposed cross-section is a zoned earthfill dam with 2 horizontal to 1 vertical upstream and downstream slopes and consists of an upstream seepage control blanket and a central till core extending below ground surface by 3 m to cut off any near-surface abandoned creek beds or other pervious zones. The proposed dam will be constructed under spring/summer conditions and all materials placed above water level must be compacted in maximum 0.3 m lifts. Materials placed below water level should be placed in a single lift with precautions being taken to ensure that loose material is displaced at the advancing face of the fill and that post construction settlement is minimized. Where two fills are advanced in water towards one another it is mandatory to make provisions before closure for removal of the accumulated loose material which has been displaced by the advancing fill fronts.

The depth of foundation preparation required will be determined in the field. To avoid costly well point dewatering of the excavation, it is proposed that the subexcavation be done in the wet with as much dewatering as possible with simple sumps and that the subexcavation materials be carefully monitored by a qualified engineer as they are excavated.

The amount of abutment preparation required will also be field determined. Excavation of ice rich frozen soils within the foundation area of the dam will be necessary and gravel blanketing of the cut slopes and permafrost area 20 m downstream of the dam toe is recommended.

The upstream blanket has been divided into primary and secondary components. The primary component will be a good quality till properly compacted and constructed above water. The secondary component will consist of initially frozen waste excavation from the Diversion Canal, compacted as a single lift after thaw using the most practicable means available.

Upstream of the core will be a granular zone which, although not excessively coarse grained, must be as cohesionless as possible so that any core cracks will be healed by seepage induced transfer of this cohesionless material. Materials which best meet this requirement are silty sands which occur locally, such as in the gravel ridge deposit.

A filter zone downstream of the core is intended to prevent piping of core materials into segregations of the coarse material of the adjacent zone. The filter material should be clean and sandy and devoid of cobbles and coarse gravel.

Shell Type I and Shell Type II materials should be considered as general fills, the difference between them being that Type I materials may be fine grained whereas Type II should contain less than 5 percent of minus No. 200 sieve. Type I materials could consist of reject core borrow. Type II materials would be terrace sand and gravel.

In view of the nature of the Cross Valley Dam foundation, settlements of about 0.8 m are expected. Such a settlement would be expected to occur over most of the length of the dam and therefore a uniform dam crest elevation of 1065.8 m has been selected for construction.

Assuming the seepage control elements discussed above are in place, the seepage through and beneath the Cross Valley Dam is computed to be about 0.03 m^3 /sec. If the secondary blanket is ruptured the seepage loss would be about 0.04 m^3/sec. These computed seepage flows are judged indicative of acceptable seepage reduction in view of the allowable design quantity of 0.15 m^3/sec. Precise prediction of seepage losses from the retention pond are not possible because the local stratigraphy and geology of the dam foundation are not known with complete certainty. For example, the occurrence of abandoned creek beds at depth below the seepage cutoff elevation cannot be precluded based on existing knowledge of valley bottom conditions in the vicinity of the Cross Valley Dam and its associated upstream blanket. And such abandoned creek beds could also daylight upstream of the proposed upstream blanket. The seepage estimates documented in Appendix VI are derived from an assessment of permeability based on experience with other water retaining structures involved in Cyprus Anvil's tailings disposal, the gradation of samples recovered in the field investigation, and from the information obtained when drilling air rotary boreholes.

7.3 Intermediate Dam

The Intermediate Dam differs from the Cross Valley Dam because its primary purpose is to retain tailings. It is expected that the dam will be built in two or more stages with the design crest elevation of the first stage being 1068 m. The proposed ultimate elevation is to be 1083 m, the retained tailings pond being lower than the invert elevation of the diversion canal at this location.

Because the Intermediate Dam will be constructed in at least two stages and a tail water will develop on the downstream side as a result of the retention pond between the Intermediate and Cross Valley Dams, the foundation of the ultimate Intermediate Dam must be completed to El. 1064 m to allow subsequent construction activity. All materials must be compacted according to the specifications for dam fill placement. The extent of ultimate section construction assumes that the ultimate dam will be raised using downstream construction techniques with a downstream slope of 2 horizontal to 1 vertical. The initial construction must assume this design approach although it is conceivable that a centreline construction could be used if tailings are spigotted against the upstream face of the dam. This latter method is presently being used for raising the existing dam and is quite economical because readily available tailings materials are used to form a significant proportion of the embankment volume and to keep the beach edge well away from the face of the constructed section.

Cross-sections of the proposed Intermediate Dam are presented on Figures 7-7 and 7-8. In general, the remarks stated previously for the Cross Valley Dam concerning fill placement and construction also apply to the Intermediate Dam. The proposed cross-section in the vicinity of Rose Creek (Figure 7-7) is similar to that recommended for the Cross Valley Dam except that the base raising for the ultimate dam is required and the upstream seepage control blanket is not required. The recommended construction crest elevation for this reach of the dam is 1068.8, allowing 0.8 m of settlement which will result from compression of the embankment, its foundation, and the foundation subexcavation replacement materials. As for the Cross Valley Dam, it is expected that foundation subexcavation below creek level will be necessary to remove unacceptable recent alluvium and organic debris.

Figure 7-8 presents the recommended Intermediate Dam cross-section in the upper level terrace reach. The seepage requirements of the Intermediate Dam, namely that no more than 0.23 m^3/sec should seep through the dam and its foundation, dictate that seepage control measures be installed in the terrace area down to about creek elevation. Rather than place a central core within the terrace gravels and the associated excavation and replacement of much of the dam foundation, it is recommended that a 5 m wide inclined blanket of glacial till be placed against the trimmed wall of a terrace gravel borrow pit excavated such that the till blanket can be easily incorporated into the dam section on the top of the terrace as shown on Figure 7-8. The borrow pit wall should be trimmed back to a 2 horizontal to 1 vertical slope to avoid disturbance and loosening of the natural terrace deposits and to permit replacement of unsuitably coarse materials adjacent to the till.

It is expected that the Intermediate Dam will be constructed as soon as possible to allow disposal of tailings in the new facility and so that the closure of the Cross Valley Dam can be effected in relatively dry conditions. This is relevant to the performance of the inclined till blanket because freezing and dessication of the till will reduce its value as a seepage reduction zone.

Because the Intermediate Dam in the upper terrace area will be completed to a relatively low height and no permafrost is present, very little crest settlement is anticipated and the proposed construction elevation is 1068 m.

The remarks made above regarding the abutments of Cross-Valley Dam are also appropriate to those of the Intermediate Dam.

7.4 Emergency Spillways and Decants

Details of the proposed emergency spillways are presented on Figures 7-9 and 7-10 according to the hydraulic recommendations of Appendix IX. The profile and cross-sections shown pertain strictly to the Cross Valley Dam but similar construction is proposed for the Intermediate Dam. The locations of the spillways are shown on Figure 7-1. Tailings wastewater decants are also shown adjacent to the emergency spillways. The purpose of the emergency spillway is to provide a controlled dam overflow capability consequent to possible temporary inability of the diversion channel to totally convey the Rose Creek flows.

The spillways consist essentially of an abutment sand and gravel fill downstream of the dam embankments. The fills are graded at a 5 percent slope until the retention pond elevation is reached in the case of the Intermediate Dam spillway or until the natural ground surface is reached for the Cross Valley Dam. The decant channels are incised into the top of the spillway fills and should be continuously riprapped within their channel sections.

The spillway crest is designed to be non-erodible during the 50 year return Rose Creek flood. Some erosion of the unprotected fill forming the

5 percent outfall should be expected but the riprapped spillway crest weir is considered to adequately protect the main dam embankment. Guidebanks along the spillway sides should also be riprapped.

7.5 Diversion Dam

The dam necessary to achieve redirection of the Rose Creek flow to the new channel is located on Figure 7-1 and the proposed cross-section is shown on Figure 7-11. The diversion dam will likely be constructed in early July, 1981 after the new diversion canal is completed. This relatively small dam will probably be constructed in the wet across the existing channel of Rose Creek. Zoned earthfill would be dumped as necessary upstream of a starter rockfill dyke to reduce the seepage through and around the dyke to acceptable levels. Embankment fills outside the closure section and above the water level in the closure section should be compacted according to normal dam specifications.

The rockfill aspect of the closure section shown on Figure 7-11 is not necessary outside the closure section. The south end of the diversion dam will be continuous with the downhill dyke of the diversion canal. The north end will abut the tailings dyke of the existing tailings facility.

The design elevation of the Diversion Dam should be marginally lower than the diversion canal dyke elevation. The Diversion Dam can then be used as a fuse plug protection for the Diversion Canal in the event of larger than design floods occurring. Therefore it is recommended that the Diversion Dam be constructed to an elevation such that the desired flow capacity of the diversion channel will be utilized and the excess flow will overtop the diversion dam. The surface of the diversion dam should therefore be riprapped.

If necessary, the Diversion Dam can be easily raised at the end of tailings disposal and when the performance of the canal will have been adequately established.

7.6 North Valley Wall Interceptor

The required hyraulic cross-sections for a 50 year return period flood are presented on Figure 8, Appendix IX. The alignment of the proposed interceptor is shown on Figure 7-1.

Because most of the North Valley wall overburden is unfrozen there is no concern given here to lining the channel section. It is recommended that the proposed cross-sections in Appendix IX be constructed without armouring because it is believed that channel erosion can be treated as a routine maintenance item, and that the channel will be fully stabilized by the end of mining.

It is noted that much of the alignment follows existing creek beds and that channel excavation is required only to transfer flow westward from creek to creek. Small diversion structures will be required to divert the flows from these creek beds as indicated on Figure 8, Appendix IX.

It is proposed that the North Valley Wall Interceptor join the decant outfall of the Cross Valley Dam just beyond the centreline of this dam as shown on Figure 7-1. This will require a significant cut into permafrost in the North Valley wall which should be lined with gravel for filter and thermal insulation purposes.

7.7 Post-Construction Maintenance

Earthworks construction is traditionally accompanied by a future need for maintenance and the usual objective is that the amount of maintenance decrease with time as the works become fully attuned to the local environment. The amount of maintenance is related to the degree of conservatism adopted in design and this is partly reflected by design factors of safety. However, some aspects of design are not easily quantified and both climatic factors and variability of construction material play an important role. The final design thus becomes a melding of quantitative aspects, experience, judgement and the ability to provide maintenance on a timely basis.

Previous involvement with Cyprus Anvil's tailings facility at Faro has demonstrated that a maintenance free design is very conservative and is not generally warranted because the tailings facility can be routinely inspected by responsible mine staff who can initiate maintenance as necessary. For this reason the final design of the Down Valley Project is not a maintenance-free design. The objectives have been to provide a safe design for the project, to advantageously use available materials, and to utilize maintenance to attune the works to the environment. Decreasing annual maintenance requirements are anticipated, as has been the case with the existing tailings containment complex.

Other factors making an acceptance of maintenance appropriate pertain to the natural geological variability of materials, particularly permafrost, and the practicability of restraining the number of design variations necessary for response to the variable geology. Furthermore design compromise is necessary to accommodate practical construction. For example, the intention that the proposed diversion canal be constructed in winter conditions introduces the desirability for compaction of materials under subzero temperatures. The success of this compaction is contingent on weather, construction procedure, and variability of excavation materials, all of which can only be specified, identified, or controlled within practical limits. The need for good compaction also depends on the location within the dyke configuration.

We expect that, for certain sections of the canal dyke, acceptable compaction within the winter months will not be possible and that some remedial work will be necessary during the thawing months for the first few years of operation. Remedial work could involve reworking of poorly compacted materials to the extent of 40,000 m^3.

Other maintenance items which we expect pertain to degradation of permafrost along the canal and erosion of the canal, the dam spillways, the decant channels, and the North Valley Wall Interceptor. The canal has been designed to accommodate permafrost thaw at acceptable rates but settlements related to consolidation of ice rich fine-grained materials will inevitably occur on a local basis. Although the proposed canal is to be completely armoured, we anticipate a need to react to local conditions of glaciation and erosion, particularly in the vicinity of valley wall creek interceptions where some maintenance experience will be gained during the early operation of the canal. The emergency spillways and decants have been designed to protect the dam cross-sections from erosion by short term large flows over the dams and some repair of these structures may be recommended after such flows occur. Periodic upgrading of the decant channels which are continuously exposed to erosion may also be necessary on a scale comparable to the maintenance of the existing decant channel. The North Valley Wall Interceptor should be allowed to develop a natural armouring just as the existing creeks have done in the past. Maintenance should therefore only involve correction of problems which could lead to breaching.

The dams are expected to perform much as the existing dam. The North Abutment of the existing West Dam consists of frozen tills and colluvium and it has performed acceptably to date. The abutments of the new dams should behave similarly with allowance for gravel blanketing of the slope downstream of the dam as necessary. It is expected that thaw of permafrost will occur upstream of the Cross Valley Dam and that the secondary upstream blanket will suffer some loss of integrity in consequence; this should not affect the dam performance except that seepage quantities would be expected to increase with time. The seepage at the downstream toe of the Cross Valley Dam should be monitored with respect to quantity and turbidity and a gravel filter could be required.

Although the true extent of remedial work will only become apparent after the project is in operation we do not anticipate extensive maintenance other than that documented above. It is important to note that all of these maintenance items can be rectified within the proposed remaining 20 to 30 year operating life of the mine and most of the maintenance needs will have occurred and will have been dealt with within the first five years. Maintenance required as a result of higher than design floods and other unusual occurrences is beyond the scope of this discussion.